V3V-9000-TS VOLUMETRIC 3-COMPONENT VELOCIMETRY ON THE FLOW AT THE EXIT OF A PIPE

APPLICATION NOTE V3V-9000-TS-002

Data was taken at the exit of a pipe with inner diameter 23.4 mm using the V3V-9000-TS volumetric velocity system. The Reynolds number of the flow based on the centerline flow velocity within the pipe and the diameter, was approximately 2500, putting the flow into the transitional regime. In addition, the pipe length was less than that needed to develop a fully developed flow (this would require a length of a minimum of 3.5 m), so that the boundary layers were still forming when the flow exited the pipe and began entraining surrounding fluid. A schematic of the developing flow within the pipe, as well as the pipe exit, can be seen in Fig. 1.

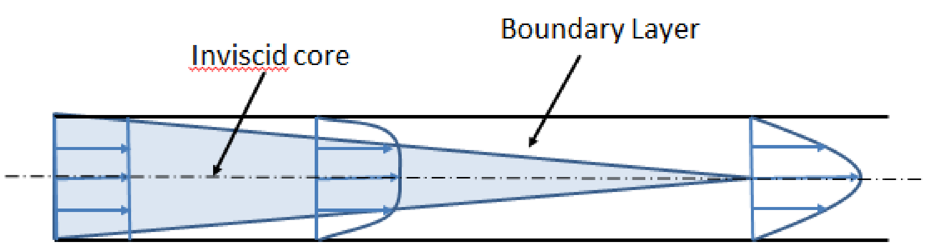

Fig. 1. Schematic of the flow evolution within a pipe (left). The current study examines data while the flow is still undergoing transition to fully developed, and the flow has exited the pipe. Photograph of the pipe exit (right).

A flow seeded with water droplets of mean diameter 0.5 to 2 µm was generated with a four-bladed fan and sent through a contraction into a 1-meter pipe with smooth walls and an inner diameter of 23.4 mm. The center of the V3V measurement volume of 50 × 50 × 20 mm was position approximately 50 mm from the exit of the pipe at an oblique angle, so that the jet exited the pipe and passed through the measurement volume diagonally at a slight angle from top to bottom, back to front, and left to right. This was done in order to maximize the spatial length of the jet that was being measured.

The V3V-9000-TS system consists of three 4MP cameras mounted in a triangular arrangement within a precision camera mount. A 200 mJ Nd:YAG pulsed laser was used to illuminate the flow volume, with a set of volume forming optics mounted at the exit of the laser. The cameras captured images of the seed particles as they were illuminated by the laser, and tracked in time to determine the particle velocity.

Figure 2 (left) shows a plot of the resulting data, which is the mean flow over 20 image sets. The planes are oriented perpendicular to the axis of the pipe, and the vectors are colored by the velocity magnitude. In order to verify the data, the measured velocity points at the center plane were plotted vs the distance from the axis of the pipe, this data can be seen in the right plot of Fig. 2. Also plotted are a parabolic profile (green line) and a cosine squared profile of the form:

$$u = U_\infty \cos\left(\pi y / 2l\right)^2$$

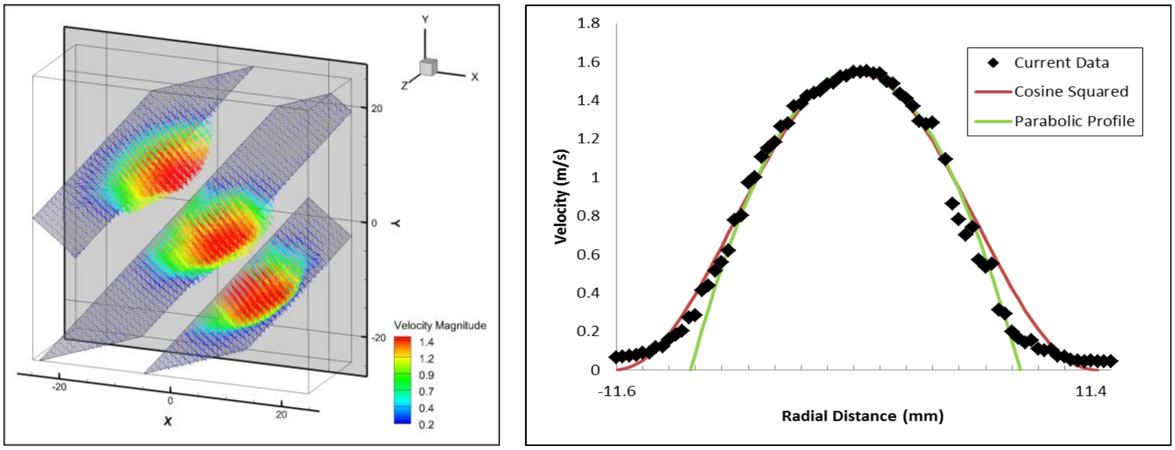

Fig. 2. Three planes orthogonal to the pipe axis showing vectors of velocity magnitude (left). The velocity profile of the center plane compared to a parabolic and cosine squared velocity profile (right).

The velocity profile deviates slightly (near the edges) from the parabolic profile since the flow at the center plane was not fully developed, and is approximately 50 mm from the pipe exit. The velocity profile has a 'flare' near the edges as the no-slip boundary condition is no longer valid, and surrounding fluid is entrained in the flow. For this reason, a cosine squared profile better approximates the flow, especially near the edges. In general, the plots show good agreement with the captured data.

A plot showing the velocity profile with an isosurface of the high-velocity core (red), as well as the location of the pipe exit, can be seen in Fig. 3.

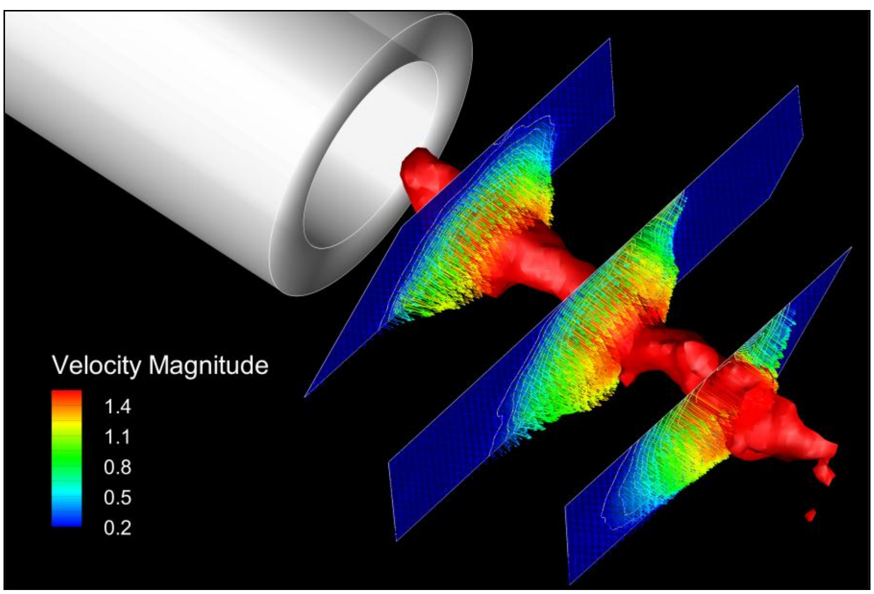

Fig. 3. The velocity profile exiting the pipe. The isosurface is velocity magnitude, and the planes are colored by velocity magnitude and show the velocity vectors.

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V3V-9000-TS-002 (12/5/2013) Printed in U.S.A.